

Report to the Administrator
on the National Research Council Report,
“The Airliner Cabin Environment and the
Health of Passengers and Crew”

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Executive Summary

The National Research Council (NRC) conducted a study and issued a report in December 2001 on *The Airliner Cabin Environment and the Health of Passengers and Crew*, as called for in the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (PL106-181). The report included ten recommendations regarding new regulations, investigations, and initiatives in public information, surveillance, and research. The report reiterated concerns raised in a similar 1986 report and highlighted the need for better data to determine the relationship between cabin air quality and health problems and complaints among passengers and crewmembers.

The Federal Aviation Administration (FAA) generally concurs with the intent of the recommendations and welcomes the report's emphasis on an increased data collection and research capacity to investigate issues related to a healthy cabin environment. FAA has begun the rulemaking process to determine if new regulations are required. It also has taken other steps short of rulemaking to address the recommendations.

Most important, FAA recognizes that technology advances in identifying chemical and biological (C/B) terrorist threats have important implications for cabin air quality. Deploying C/B sensor technology on commercial aircraft opens the way for on-board sensors for air quality markers and communicable diseases. The FAA response to NRC's recommendations should be viewed as interim steps to a much broader vision of a secure and healthy aviation system.

NRC's Recommendations 1-4 focused on specific aspects of air quality issue and called for FAA to:

- Use "quantitative evidence and rationales" to support its existing and proposed regulations related to air quality and change the ventilation standard
- Mandate the use of ozone converters or prohibit flights above 25,000 feet
- Investigate the need for particulate filters and gaseous filtration systems on all aircraft
- Require a CO (carbon monoxide) monitor in the air supply ducts to passenger cabins

FAA is tasking an Aviation Rulemaking Advisory Committee (ARAC) to review existing standards and propose revisions or new standards. However, it is not convinced of the need to monitor all of the air quality characteristics noted by NRC for routine surveillance for elevated CO concentrations. FAA prefers a system that will ensure that the flight crew is aware of an "air contaminant" event and will identify its source.

NRC's Recommendation 5 called for an investigation by FAA to determine if, because of allergy concerns, small animals should be prohibited in airplane cabins. It also recommended that cabin crews be trained to recognize and respond to severe reactions to airborne allergens. FAA recognizes that allergens in the airplane cabin are a potentially life-threatening issue for a small segment of the airline passenger population. It does not believe that prohibition of animals in the cabin would be effective. However, it will issue an Advisory Circular that incorporates the most effective industry practices regarding passenger handling procedures for allergen-sensitive

people seated close to animals. The circular also will address the importance of crewmember training in recognition and response to in-flight medical events that result from allergen exposure. In addition, every effort will be made to ensure that flight attendants and the aviation community in general have the most up-to-date information for the treatment of allergen-related medical events. Finally, information on airline policies for the transportation of animals will be disseminated to the public.

NRC's Recommendation 6 called for increased efforts to provide information on health issues related to air travel and especially on the potential risks of flying. FAA concurs with the recommendation and will continue to focus the attention of its Office of Aerospace Medicine on health issues faced by passengers and crewmembers. It also will increase the information and recommendations that are available on public web sites.

NRC's Recommendation 7 repeated its 1986 call for a regulation to require air carriers to remove all passengers from an aircraft within 30 minutes after a ventilation failure or shutdown on the ground. FAA concurs with the objective of the recommendation and believes that it can be achieved by issuing an Advisory Circular to air carriers on the subject.

NRC's Recommendation 8, 9, and 10 called for:

- An FAA surveillance program for air quality and health that would provide the data to analyze the relationship between cabin air quality and health effects or complaints
- A range of potential research efforts that would be defined, in part, by the data gathered through surveillance
- Congressional designation of a lead agency and funding for a research program with an independent advisory committee

FAA concurs with these three related recommendations and will propose that Congress designate and fund FAA as the lead federal agency for the air quality research program.

FAA also will recommend to the Secretary of Transportation that a cooperative effort with the Transportation Security Administration (TSA) be initiated to place sensor devices on U.S. air carrier aircraft. The devices would monitor cabin air quality and detect biological and chemical contamination of cabin air in a manner that warns the aircrew and locates the source of contamination.

If accepted by the Secretary of Transportation, a research council administered by both FAA and TSA would provide oversight for the monitoring and research efforts. The Safety Subcommittee of FAA's Research, Engineering and Development (RE and D) Advisory Committee could provide technical oversight. The Administrator will request additional funding from Congress to support the cabin air monitoring initiative as well as the data collection and research initiatives recommended by NRC.

Preface

Section 725 of the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (PL106-181), enacted on April 5, 2000, directed the FAA Administrator to

...provide necessary data to the National Academy of Sciences to conduct a 12-month, independent study of air quality in passenger cabins of aircraft used in air transportation and foreign air transportation, including the collection of new data, in coordination with the Federal Aviation Administration, to identify contaminants in the aircraft air and develop recommendations for means of reducing such contaminants.

The National Research Council (NRC), the principal operating agency of the National Academy of Sciences (NAS) and the National Academy of Engineering, conducted the study and issued its report, *The Airliner Cabin Environment and the Health of Passengers and Crew*, in December 2001. The report included nine recommendations to FAA and one to Congress that called for new regulations, further investigations in specified areas of concern, and increased efforts in public information, surveillance, and research.

The Federal Air Surgeon, Jon L. Jordan, M.D., took responsibility for preparing a Report to the Administrator that would summarize NRC's recommendations and present FAA's response to them. He created an inter-disciplinary group, the Airliner Cabin Environment Report Response Team (ACERRT), chaired by Charles Ruehle, M.D., Manager of the Certification Appeals Branch, Office of Aerospace Medicine. The group met weekly over a period of two months to study NRC's report, determine what has been done and is being done to address the concerns raised in the report, and develop an appropriate FAA response to NRC's recommendations.

The Report to the Administrator quotes in full each of NRC's ten recommendations, followed by the FAA response to the recommendation and a discussion of the issues on which that response was based. FAA concurs with the intent or objective of most of the recommendations, although not always with the specific proposals for action. For many of the recommendations, actions that address the underlying concerns have been taken already or are in progress.

Viewed as a whole, NRC's report should be seen as evidence that passengers and crewmembers on commercial aircraft have a continuing concern about a variety of health and comfort problems that they ascribe to poor air quality in airliner cabins. Such concerns are not a new phenomenon. NRC conducted a similar study fifteen years ago and presented similar findings and recommendations. Some actions were taken as a result of the 1986 study, notably the ban on smoking on all U.S. domestic flights. However, neither NRC nor FAA has sufficient data to assess objectively passenger and crewmembers' complaints, design effective interventions, or determine whether rulemaking or guidance will be the most effective tactic for making changes.

To monitor cabin air quality and use the resulting data to establish or rule out cause-and-effect relationships between air quality and complaints of discomfort and health problems will be a costly enterprise. Until now, the expense of cabin air monitoring has been borne by industry, but industry is naturally resistant to making significant new investments in cabin air monitoring

equipment in the absence of clear evidence of a related health problem. Congress has thus far not been persuaded to fully fund a research effort of the magnitude envisioned by NRC.

The tragic events of September 11, 2001 were not addressed by the NRC report. However, they have raised the government and the public's consciousness of the threat of chemical and biological (C/B) terrorism, including the threat on board commercial airliners during flight. Combating terrorism and increasing the safety and security of airline passengers and crewmembers overlaps with the air quality and health issues studied by NRC.

The Department of Defense (DOD) has invested heavily over the past decade in new sensor technology for detecting C/B agents and in developing miniaturized sensors. Deployment of C/B sensor technology on commercial aircraft would open the way for onboard sensors for carbon dioxide, carbon monoxide, and ozone as well as for human communicable diseases. Sensor technology for C/B agents has not yet been adapted to air quality markers, but preliminary inquiries to the scientific community suggest that adaptation is possible.

To be fully effective, sensors for cabin environmental monitoring must identify target agents in real time and communicate the identification to appropriate authorities. The identification step may be integral to the sensor device or it may be achieved by telemetry of sensor reactions to a base station for analysis. Technology already exists that makes these concepts feasible for cabin air monitoring.

The responses to NRC's recommendations that comprise this report describe the actions FAA is taking to address the air quality issues that it raised. These actions are important and necessary, but they do not address the security issues that DOT now faces. This report serves as a basis for achieving a much broader vision that could not have been fully appreciated before September 11. The compelling vision of the future that is now emerging is of a global network of surveillance systems, operating 24 hours a day, communicating via satellite with base stations for real-time identification of agents, data analysis, and threat alert. If continuous monitoring for aircraft cabin contaminants becomes a component of a global surveillance system, the problems of air quality, disease transmission, and C/B threat could be managed effectively to the great benefit of airliner passengers and crewmembers.

NRC Recommendation 1 – Air Quality Regulations

FAA should rigorously demonstrate in public reports the adequacy of current and proposed FARs related to cabin air quality and should provide quantitative evidence and rationales to support sections of the FARs that establish air quality-related design and operational standards for aircraft (standards for CO, CO₂, O₃, ventilation, and cabin pressure). If a specific standard is found to be inadequate to protect the health and ensure the comfort of passengers and crew, FAA should revise it. For ventilation, the committee recommends that an operational standard consistent with the design standard be established.

Response

NRC made several recommendations regarding air quality in the airliner cabin environment. Its first recommendation included a general proposal that FAA use “quantitative evidence and rationales” to support its existing and proposed regulations related to air quality, and a specific proposal to change the ventilation standard.

Existing FAA air quality regulatory requirements reflect a general consensus of aircraft manufacturers that the minimum levels of CO (carbon monoxide) and CO₂ (carbon dioxide) are good indicators of overall air quality. The existing design standards have assured airplane passengers and crewmembers an acceptable cabin environment during normal operations. In fact, the environmental control systems on board commercial transport category airplanes provide an environment that is equivalent to or better than that of other forms of commercial transport when they are properly operated and maintained. Three corroborative studies are excerpted in a Research Addendum below.

However, FAA rulemaking may not have kept pace with public expectation and concern about air quality and does not afford explicit protection from particulate matter and other chemical and biological hazards.

FAA concurs with the intent of NRC’s recommendation and is in the process of tasking an Aviation Rulemaking Advisory Committee (ARAC) to review the existing standards and, if they are inadequate, to propose revisions and/or new standards. The ARAC tasking directs its working group to review 14CFR Part 25, §§25.831, (a) through (d) and 25.832¹, and to:

Evaluate the current transport category airworthiness regulations regarding the airplane environment to determine if revisions are needed to ensure that the ventilation systems provide a suitable environment for crew and passengers.

Assess the following issues:

- The types of airplane system failure conditions that should be addressed (e.g. engine lubricant leakage, hydraulic fluid leakage, etc.).

¹ See Appendix 1 for full text of all CFRs cited

- The types of ventilation system operating conditions that should be evaluated throughout the airplane's flight envelope as well as transient conditions (e.g., reduced ventilation rates during "packs-off" takeoff procedures).
- The appropriate ventilation rate to ensure proper control of ozone, carbon dioxide and carbon monoxide. The working group will also consider any other contaminants of concern identified by the current National Academy of Sciences committee on aircraft air quality.
- The appropriate cabin pressure altitude, humidity, and the maximum and minimum sustained temperature limits needed to maintain crew performance and crew and passenger health and comfort levels.
- The relevant NASA, U.S. Armed Forces, NIOSH, OSHA, FAA, and their respective European counterparts, academia, and industry standards for established concentration limits for particulates, chemical, biological, and other contaminants for the respective occupational and public health limits.
- Recommendations of the FAA Office of Aviation (now Aerospace) Medicine and the National Institute of Occupational Safety and Health Study, the National Academy of Science investigation of passenger cabin air quality (scheduled for completion in FY02), the U.K. House of Lords, Select Committee on Science and Technology, 5th Report HL Paper 121-1, titled "Air Travel and Health," published 22 November 2000; and other new European or U.S. industry investigations of air quality.

Without attempting to predict the outcome of the ARAC review, it appears that the air quality regulations may evolve into a more comprehensive standard that adopts applicable parts of an existing consensus standard for environmental health.

Discussion

Present federal regulations governing the cabin environment of large commercial transport category airplanes are found under §§25.831 (ventilation), 25.832 (cabin ozone concentration), and 25.841 (pressurized cabins). Together, the three regulations provide the minimum standard that manufacturers of large transport category aircraft (i.e. aircraft of more than 12,500 pounds maximum certified takeoff weight operated by an air carrier) must meet.

The intent of §25.831 is to ensure that passengers and crewmembers have sufficient uncontaminated air to allow reasonable comfort during normal operating conditions and after a "probable" failure of any system that would adversely affect the cockpit or cabin ventilation air. Of special note are the requirements for ventilation airflow per occupant, (i.e., 0.55 lbm per minute) and carbon monoxide. While no specific oxygen requirement was ever specified, the 10 cfm of fresh air provides more oxygen than is necessary for respiration while carrying out normal activities. While the hazardous nature of CO and CO₂ are known from many sources, FAA selected the levels that seemed appropriate to the airplane environment.

Section 25.832 was added in January 1980 following complaints from crewmembers and passengers about various adverse health effects associated with ozone in the airplane cabins. Ozone is a gas that can be irritating to the respiratory tract and eyes when present in high enough concentrations. Because the level of discomfort is proportional to the level of activity of the parties exposed, cabin attendants are more likely to be adversely affected. The ozone limits in

this section are intended to protect passengers and crewmembers from exposure to concentrations high enough to be hazardous.

Section 25.841 provides standards for pressurized compartments in transport category airplanes and addresses the requirements for various controls and pressure relief valves. Testing required for demonstrating compliance with many of the requirements of this section is addressed in §25.843.

The ARAC rulemaking process will determine whether changes are needed in the regulations related to air quality. It will also provide an opportunity to address safety issues that may be related to air quality.

In 1999, FAA concluded a preliminary internal review of its event database between January 1978 and December 1999 involving “air quality” in the aviation Accidents and Incident Data Systems (AIDS). The review is described in detail in the Research Addendum that follows.

Of 240 events identified in the search, about 60 were “airplane ventilation toxic contaminant events.” Of the 60 events, 24 resulted in statements from crewmembers indicating that their performance was impacted. In 2000, FAA broadened its investigation to include incidents where the database included a reference to “smoke in cockpit” or “smoke in cabin.” These investigations revealed that the number of events per flight is statistically very low. However, during some events, crewmembers were impaired in the performance of their duties. There also have been a number of reports of foreign airline crew members having their performance impaired to the point that they had to be assisted in performing their flight duties or had to relinquish their flying duties during the flight. This is a matter of great concern to FAA. Furthermore, during the investigation, a potential safety problem became apparent regarding system isolation during an air contaminant event. The ARAC working group will address this issue.

Evaluations of FAA Aviation Safety Research System reports (ASRS) database and FAA Service Difficulty Reporting System (SDRS) database are in progress and will be shared with the ARAC.

FAA remains concerned over the discrepancy between the number of reported events filed in our National Aviation Safety Data Analysis Center (NASDAC) databases and the number reported by industry organizations. Currently, FAA only requires that a report be filed when a direct impact on safety has occurred. Additional requirements to file a report after an “air quality incident” will be discussed by the ARAC.

Research Addendum

The following research studies support FAA’s position on airliner cabin air quality.

1. “Environmental Survey on Aircraft and Ground-Based Commercial Transportation Vehicles,” Harvard School of Public Health, May 31, 1997. Measurement data and information are specific to the Boeing 777 airplane.

Overall, while in the air, airplanes had (except for subways) the lowest CO₂ concentrations of the vehicle types. Low CO₂ concentrations are indicative of relatively high per-person ventilation, since CO₂ is primarily derived from human occupants. On the other hand, relatively high CO₂ concentrations and temperature during the boarding process indicate relatively low ventilation rates, compared to cruise periods in aircraft and to travel in other types of vehicles. Passengers may be exposed to these uncomfortable conditions for periods ranging from 30-60 minutes.

In addition, concentrations of CO, NO₂, and particles were lowest for aircraft, perhaps, in part, indicating the good quality of supply air.

Humidity was also lowest for aircraft. The very low humidity during actual travel (cruise), compared to other transportation modes, results from the very low water content in supply air.

Of the volatile organic compounds detected, only ethyl alcohol and acetone were highest in aircraft. The high ethyl alcohol levels probably reflect the intensive beverage service that occurs during cruise in aircraft. Ethyl alcohol and acetone are human effluents, and acetone is also used in a variety of commonly found products

Concentrations of biological agents were generally low in aircraft compared to other transportation modes, outdoor air, and residential environments. Although geometric mean values for dust mite allergens were higher for airplanes than for other vehicles or homes, both mean and maximum levels were quite low (below levels that are considered to pose a risk for either sensitization or exacerbation of symptoms). Cat allergen levels were above the hypothetical limits for sensitization, but below those considered necessary to induce acute symptoms. It should be noted that sensitization requires chronic exposure over many months. It is also important to note that cat allergen is ubiquitous in modern environments unless specifically and rigorously excluded.

2. "Relate Air Quality and Other Factors to Symptoms Reported by Passengers and Crew on Commercial Transport Category Aircraft," Consolidated Safety Services, Inc., American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Research Project 957-RP, Final Report, February 1999. Measurement data and information are specific to the Boeing 777-200 airplane.

The mean CO₂ concentrations measured in this study were similar to levels measured by other researchers including the 1989 U.S. Department of Transportation study where "measured CO₂ levels averaged 1,500 ppm".

Carbon dioxide levels are approximately 50% higher than the surrogate levels recommended in ASHRAE Standard 62-1989 for public buildings. However, there are no published studies that suggest the CO₂ levels encountered on aircraft will result in adverse health effects. In fact, people are likely exposed to much higher CO₂ levels in

their own residences than in the aircraft. The 1,000 ppm concentration recommended in ASHRAE, 62-1989 is not a health hazard level, but a comfort level standard set to satisfy the body odor perception of 80% of unadapted persons (visitors) in an occupied space. Additional data needs to be collected on the aircraft to adequately determine what the CO₂ comfort threshold is for the commercial aircraft. It appears however, based on the results of the data that was collected during this study, that the CO₂ comfort odor threshold for aircraft will be higher than that of buildings, possibly around 1,500 ppm.

Based on the results of this study and other studies that were reviewed, including the NIOSH Alaska Airlines Health Hazard Evaluation, harmful levels of carbon monoxide are not likely to occur during routine commercial aircraft operations.

While harmful ozone concentrations were not recorded during this study, elevated ozone plumes can occur at higher altitude polar routes, thereby placing passengers and flight attendants that frequently travel these routes at an increased risk for ozone-related health effects.... More research concerning the health effects of short-term ozone exposure is needed, especially in-flight attendants and passengers that travel polar routes where high levels of atmospheric ozone are present.

Exposure to harmful concentrations of volatile organic compounds (VOCs) does not appear to present a significant health hazard for passengers or flight attendants. This study, as well as other published and unpublished data seem to indicate that concentrations of total VOCs are lower on aircraft than in other public environments.

This study and other studies performed to date, indicate that respirable suspended particulate (RSP) levels during flight are very low when compared with other indoor environments. There is an indication that elevated RSP levels (in the 200 µg/m³ range) are encountered for brief periods during boarding and deplaning. However, these levels are not likely high enough to present a significant health hazard, if one assumes that the increased levels of RSP are generated by passengers moving around and storing baggage and other personal effects. Persons with allergies to human activity allergens such as fabric fibers, animal dander and dust mites may experience symptoms similar to other crowded environments such as buses, subways, theaters, and auditoriums.

Based on the results of this study ... and other published and unpublished research that was reviewed, there does not appear to be data supporting an increased risk of airborne disease producing bacteria and fungi associated with commercial airline travel. This is because data generally suggest that airborne levels of bacteria and fungi found on commercial aircraft are very low when compared with levels found in outdoor environments and in public buildings. Also, a study conducted by the Centers for Disease Control, concerning the transmission of Mycobacterium Tuberculosis onboard several commercial airline flights, concluded that it was unlikely that the organism was spread via the aircraft ventilation system. This is important since there are some researchers that contend an increase in the amount of outside air will lower the risk of transmission of disease producing bacteria and fungi. If there is an increased risk of the transmission of bacteria, fungi and viruses onboard commercial aircraft it is likely

associated with the close proximity of the passengers. Therefore, increasing the amount of outside air will not minimize this type of disease transmission.

Results of this study indicated the percent of oxygen onboard commercial aircraft remains relatively constant at approximately 21%. The oxygen percentage is not affected by the recirculation system due to the much larger supply of oxygen compared to the consumption rate. Obviously, the partial pressure of oxygen is reduced significantly at an altitude equivalent of 7,000 feet (124 mm Hg) than at sea level (160 mm Hg). This decrease in the partial pressure of oxygen should not pose a significant health hazard to healthy passengers and flight attendants. People with health problems that could be exasperated by lower oxygen pressures should consult their physician before flying. More data should be collected on other aircraft types to determine if oxygen concentrations are being maintained at a safe concentration.

The relative humidity measured during the study averaged approximately 14% in the economy section while the aircraft was aloft. The minimum relative humidity recorded was 6.4% and this occurred when the recirculation fans were turned off (with 100% of the cabin air being supplied from the outside or bleed air).

3. "HETA 90-266-2281, Alaska Airlines, Seattle, Washington," National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Report, January 1993. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control. Measurement data and information are specific to the McDonnell Douglas MD-80s and Boeing 727 and 737.

Results of NIOSH environmental monitoring (continuous and grab measurements) aboard the "worst case" and "normal" MD-80 flights did not reveal a health hazard. In-flight average ranges for cabin air pressure (654-656 millimeters of mercury [mm Hg]), carbon dioxide (550-1191 parts per million [ppm]), nitrogen dioxide (not detected, <2.5 ppm), oxygen (20.75-20.84%), ozone (0.005-0.017 ppm), temperature (74-75°F), total particulates (0.003-0.026 milligrams per cubic meter [mg/m³], and relative humidity (20-21%) were consistent with previous studies of commercial aircraft cabin air quality. The results indicated that cabin conditions commonly may not meet the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) comfort criteria for temperature, relative humidity, and carbon dioxide concentrations, particularly during gate time. The highest instantaneous and in-flight average carbon dioxide concentrations, 4882 and 1191 ppm, respectively, were measured on the "normal" flight, which unintentionally had the longest gate time. In-flight grab sample results for carbon monoxide on the test flights were low (2-6 ppm), all below the ambient level of 9 ppm measured at Seattle/Tacoma airport. Results of direct reading continuous monitoring for CO were inconclusive (due to instrument miscalibration in the field); however, the consistent finding of apparent short-term peaks (5-10 ppm above baseline) indicated a possible source of CO exposure and the need for follow up monitoring (see below).

Several methods were used to sample volatile organic compounds (VOCS) in cabin air on the test flights. Continuous in-flight monitoring with photoionization detectors found average total VOCs concentrations to be well below 10 ppm toluene equivalent (range: 1.8-3.2 ppm toluene equivalent). A brief, relatively high concentration peak in total VOCs was measured at one seat location (72-176 ppm toluene equivalent); no unusual events or odors were associated with the event. The major compound identified in sampling for VOCs was ethanol; other compounds found in trace (non-quantifiable) concentrations were cyclopentadiene, 1,1,1 trichloroethane, benzene, trichloroethylene, perchloroethylene, toluene, xylene isomers, siloxane compounds, limonene, and aliphatic compounds. No ethanol was detected in samples collected prior to take off (<0.5 ppm); in-flight average concentrations were low, but quantifiable (range: 0.9-4.6 ppm). It is likely that alcoholic beverages served during the flights were the source. No aldehydes were detected in air samples (<0.07 ppm). Neither grab air sampling method (1-liter gas bag and 50-mL evacuated container) tested for possible flight crew use during incidents was satisfactory for sampling for trace levels of VOCs.

Follow up monitoring for CO was conducted by Alaska Airlines and the AFA (with electrochemical dosimeters) on 10 non-incident commercial flights, which involved nine McDonnell Douglas (MD-80s) and Boeing (727 and 737) aircraft, five of which had been involved in a previous incident. The ranges for time-weighted average (TWA) personal and area CO concentrations were < 1-5 ppm (5 samples) and < 1-7 ppm (59 samples), respectively; all were well below the NIOSH Recommended Exposure Limit (REL)-TWA (adjusted for altitude) of 20 ppm. Corresponding instantaneous peak CO concentrations ranged from < 1 to 25 ppm, all well below the NIOSH REL-Ceiling Limit of 200 ppm; however, the consistent finding of apparent CO peaks on commercial flights suggested either a common source or interference. During two additional non-incident commercial flights, NIOSH investigators conducted monitoring for CO using paired sealed and unsealed dosimeters, and a laboratory-based grab sampling method. The results indicated that a CO peak measured with a dosimeter (30-35 ppm) was due to an interfering gas or vapor.

4. In 1999, FAA concluded a preliminary internal review of events involving “air quality” in the aviation Accidents and Incident Data Systems (AIDS) database. The database is part of FAA National Aviation Safety Data Analysis Center (NASDAC) database and it contains data records for general aviation and air carrier incidents that do not meet the damage or injury thresholds of the National Transportation Safety Board (NTSB) definition of an accident. The search was conducted on *Air Carrier/Commercial* operations within the United States between January 1978 and December 1999 using the search string: odor, fume, gas, smell.

The 240 events identified in the search included, as the largest group of events, 144 in the category of “electrical failure” (i.e., recirculation fan failures, electrical component failures, arcing of wires, etc.). Approximately 60 events were “airplane ventilation toxic contaminant events,” where failures occurred in airplane, engine, or auxiliary power unit (APU) systems that may have caused tri-cresyl phosphate lubricants, or phosphate ester hydraulic fluids, or

products of decomposition from these fluids to enter the cockpit/cabin ventilation systems. Of these 60 events, approximately 24 resulted in statements from crewmembers indicating that their performance was impaired.

To put the number of events in proper context, it is necessary to relate it to the number of airplane departures and/or flight hours. Using reported data from 1989 through 1996 and a linear extrapolation to estimate data for 1997, 1998 and 1999, from January 1989 through December 1999 there were approximately 82,570,744 departures with a total accumulated aircraft hours of 121,241,680. An AIDS search over the same period identified a total of 167 events of which approximately 14% were connected to air contaminants present in the ventilation system. These results indicate a likelihood of an event occurring as 0.000000278 per departure, or 0.000000189 per aircraft hour.

In 2000, FAA broadened its investigation by conducting a search of the database using the search string: “smoke in cockpit,” “smoke in cabin,” odor, fume, gas, smell. The search was conducted on *Air Carrier/Commercial* operations within the United States between January 1978 and December 1999 and resulted in a match with approximately 416 events. The result of that search appears in Tables 1-3. The numbers of occurrences are given per an indicator of root cause (i.e., the failure that led to the event). In addition, Figure 1 shows the breakdown per general system failure. To put these events into perspective, actual data on the total number of aircraft hours originating from U.S. airports from 1987 through 1996 was used. The total number of “air quality” events during this period was approximately 222; the total number of aircraft hours was 100,551,114. The likelihood of an “air quality” event occurring on a large commercial transport airplane was 0.00000221 per aircraft hour or 2.2 events every 1,000,000 aircraft hours. Because there is currently no requirement that crewmembers report “air quality” events, however, these numbers may understate actual occurrences.

Table 1: FAA AIDS Results from 1991 through 1999 for all Air Carrier Part 121 US Airplanes; Search String: “smoke in cockpit”, odor, fume, vapor, smell, gas

Air Transport Association Code	1999	1998	1997	1996	1995	1994	1993	1992	1991
21XX - Air Conditioning System	6	7	4	4	4	6	4	4	9
22XX - Autopilot									1
23XX - Communications System	1			1			1		1
24XX - Electrical System	6	6	5	2	1	1	4	6	2
25XX - Interior	1	1	2	1	1				1
26XX - Fire Protection			2	1		1			
27XX - Flight Control System	1								1
28XX - Fuel System									
29XX - Hydraulic System		1	2	1			2	1	
30XX - Anti-Ice System	1			3	2	2		1	
31XX - Instruments							1		
3210 - Doors		1							
323X - Landing Gear	1	1	1						
33XX - Lighting System	2			1	1		2	3	5
34XX - Navigation System			1		1		1		1
36XX - Pneumatic System		1							
38XX - Waste & Water System									
49XX - Airborne APU System	2	1	1	1	1	1	1	3	3
56XX - Window								1	
61XX - Propeller System					1				
72XX - Engine System	1	2	1	1	4	2	6	1	
73XX - Engine & Fuel Control									
74XX - Engine Ignition		1							
75XX - Engine Bleed System	1		1						
76XX - Engine Controls								1	
77XX - Engine Indicating		1							
78XX - Engine Exhaust System	1				1				
85XX - Engine					1				
8550 - Engine Oil									
HAZMAT	1		1				1		1
Msc, Unsafe Acts by 3rd Party	3	2	3	3	3	3	3	4	4
Unknown, Undetermined	2	4	1		1	1			

Table 2: FAA AIDS Results from 1982 through 1990 for all Air Carrier Part 121 US Airplanes; Search String: “smoke in cockpit”, odor, fume, vapor, smell, gas

Air Transport Association Code	1990	1989	1988	1987	1986	1985	1984	1983	1982
21XX - Air Conditioning System	7	9	6	3	3		1	4	3
22XX - Autopilot		1							
23XX - Communications System			1			1			
24XX - Electrical System	3	2	5	1	1		1	2	3
25XX - Interior	2	1	2	1	1	2		1	3
26XX - Fire Protection		1							
27XX - Flight Control System	1	1			1	1			1
28XX - Fuel System		1	1		1				
29XX - Hydraulic System	1					1	1		
30XX - Anti-Ice System	1						1		
31XX - Instruments									
3210 - Doors									
323X - Landing Gear					1			2	1
33XX - Lighting System	5	3	1		1	1	2	2	1
34XX - Navigation System			1				4		
36XX - Pneumatic System	1	1							
38XX - Waste & Water System		1		1				1	
49XX - Airborne APU System	1	2	1						
56XX - Window									
61XX - Propeller System									
72XX - Engine System	1	1	1	1	1	1		1	
73XX - Engine & Fuel Control		1						1	
74XX - Engine Ignition									
75XX - Engine Bleed System	1		1						
76XX - Engine Controls									
77XX - Engine Indicating									
78XX - Engine Exhaust System		1							
85XX - Engine									
8550 - Engine Oil			1						
HAZMAT	1					1			
Msc, Unsafe Acts by 3rd Party	2	2		2	2	2		2	3
Unknown, Undetermined									

Table 3: FAA AIDS Results from 1978 through 1981 for all Air Carrier Part 121 US Airplanes; Search String: “smoke in cockpit”, odor, fume, vapor, smell, gas

Air Transport Association Code	1981	1980	1979	1978
21XX - Air Conditioning System		4	5	2
22XX - Autopilot				
23XX - Communications System				
24XX - Electrical System	1	1	1	
25XX - Interior		1	2	
26XX - Fire Protection				
27XX - Flight Control System				
28XX - Fuel System		1		
29XX - Hydraulic System				1
30XX - Anti-Ice System		1		
31XX - Instruments				
3210 - Doors				
323X - Landing Gear				
33XX - Lighting System				1
34XX - Navigation System		2	1	1
36XX - Pneumatic System				
38XX - Waste & Water System				
49XX - Airborne APU System		2		
56XX - Window				
61XX - Propeller System				
72XX - Engine System	1	1	1	
73XX - Engine & Fuel Control				
74XX - Engine Ignition				
75XX - Engine Bleed System			1	
76XX - Engine Controls				
77XX - Engine Indicating				1
78XX - Engine Exhaust System				
85XX - Engine				
8550 - Engine Oil				
HAZMAT			1	1
Msc, Unsafe Acts by 3rd Party	1	5	2	5
Unknown, Undetermined		1		

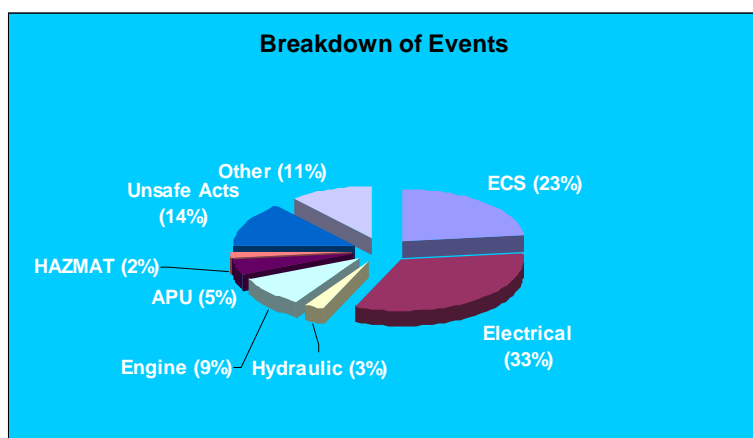


Figure 1: Sources of “smoke in cockpit”, odor, fume, vapor, smell, gas in the cabin or cockpit; 1978 through 1999

NRC Recommendation 2 – Regulations for Ozone

FAA should take effective measures to ensure that the current FAR for O₃ (average concentrations not to exceed 0.1 ppm above 27,000 ft, and peak concentrations not to exceed 0.25 ppm above 32,000 ft) is met on all flights, regardless of altitude. These measures should include a requirement that either O₃ converters be installed, used, and maintained on all aircraft capable of flying at or above those altitudes, or strict operating limits be set with regard to altitudes and routes for aircraft without converters to ensure that the O₃ concentrations are not exceeded in reasonable worst-case scenarios. To ensure compliance with the O₃ requirements, FAA should conduct monitoring to verify that the O₃ controls are operating properly (see also recommendation 8).

Response

NRC recommended that FAA ensure that existing regulations regarding O₃ (ozone) concentration are met by mandating the use of ozone converters or prohibiting flights above 25,000 feet (i.e., below the minimum altitude applicable for existing rules.).

FAA concurs with the intent of the recommendation as an appropriate and measured response to the potential of new airplanes to cruise at higher altitudes and to changes in the atmospheric composition of trace gases. As noted under the response to NRC's Recommendation 1, FAA is in the process of tasking an ARAC to review the existing standards and, if they are inadequate, to propose revisions and/or new standards. The ARAC tasking directs its working group to review 14CFR Part 25, §§25.831(a) through (d) and 25.832, and to:

Evaluate the current transport category airworthiness regulations regarding the airplane environment to determine if revisions are needed to ensure that the ventilation systems provide a suitable environment for crew and passengers.

Assess the following issues:

- The appropriate ventilation rate to ensure proper control of ozone, carbon dioxide and carbon monoxide.

The working group will also consider any other contaminants of concern identified by the current National Academy of Sciences committee on aircraft air quality.

The ARAC review also will address design mitigation strategy and means of compliance. Without attempting to predict the outcome of the review, it appears that an ozone converter (i.e., a device that removes ozone from the air) on large transport category airplanes may be the most robust methodology to ensure consistent, successful compliance with regulations governing airplane ozone control.

Discussion

Ozone is a gas that can be irritating to the respiratory tract and eyes when present in high enough concentrations. The existing Federal Aviation Regulations governing ozone in the airplane cabins is 14CFR §25.832. There is a parallel requirement in the operating rules (§121.578). The

regulation was adopted in January 1980 after complaints and a petition for rulemaking by crewmembers and passengers. The objective of the rule is to protect cabin occupants from various adverse health effects associated with ozone in the cabin environment by setting maximum standards for concentrations of ozone in the occupied areas of transport category airplanes.

Although the results of two relevant studies (quoted in the Research Addendum below) have shown that ozone concentration does not represent a threat to the occupants of large transport category airplanes, additional research may be needed. FAA's regulatory guidance material regarding ozone concentration² was developed in the 1960's and 70's. Information from NASA³ indicates that the ozone content and distribution have changed significantly since then. In addition, future airplanes will be able to cruise at higher altitudes in the stratosphere where the concentration of external ozone is much higher than in the troposphere.⁴

Research Addendum

1. "HETA 90-266-2281, Alaska Airlines, Seattle, Washington," National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Report, January 1993. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control. Measurement data and information are specific to the McDonnell Douglas MD-80s and Boeing 727 and 737.

Results of NIOSH environmental monitoring (continuous and grab measurements) aboard the "worst case" and "normal" MD-80 flights did not reveal a health hazard. In-flight average ranges for cabin air pressure (654-656 millimeters of mercury [mm Hg]) ... ozone (0.005-0.017 ppm) ... were consistent with previous studies of commercial aircraft cabin air quality.

2. "Relate Air Quality and Other Factors to Symptoms Reported by Passengers and Crew on Commercial Transport Category Aircraft", Consolidated Safety Services, Inc., American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Research Project 957-RP, Final Report, February 1999. Measurement data and information are specific to the Boeing 777-200.

Continuous ozone (O₃) measurements were collected using a direct-reading, electrochemical sensor, with measurements averaged every five minutes.... The mean O₃ level for all flights while the aircraft was aloft was 51 ppb [parts per billion by volume]. The mean concentration for domestic flights was 46 ppb, while the mean level for international flights was 53 ppb. The mean concentration was higher on the ground, 62 ppb during boarding and 77 ppb during deplaning, than when the aircraft was aloft. The highest five-minute mean recorded was 122 ppb during an international flight between Washington and London. Of the 287 five-minute mean periods that were recorded when the aircraft was aloft, 100 ppb was only met or exceeded during nine periods. [The

² Advisory Circular AC 120-38, Transport Category Airplanes Cabin Ozone Concentrations

³ NASA Earth Observing System (EOS) Handbook available at <http://eosps0.gsfc.nasa.gov/>

⁴ For example, Table 1, "Major and Selected Trace Gases in the Atmosphere", "Global Biomass Burning: Atmospheric, Climatic, and Biospheric Implications, Levine, J.S., ed, published by MIT press, Inc, 1991,

accuracy of the ozone sensor was plus or minus 100 ppb, therefore these results cannot be considered conclusive.)“

Analysis of the symptoms data collected from the comfort questionnaire indicated that passengers did not significantly experience ozone-related health symptoms. For example, shortness of breath and dizziness, two symptoms often associated with ozone exposure were the two symptoms least experienced by passengers, 4.7% and 5.7%, respectively. Other symptoms associated with ozone exposure (e.g. headache; dry itchy or irritated eyes; and sore, dry throat) were reported more frequently however, these symptoms can also be caused by other confounding factors such as low humidity.

NRC Recommendation 3 – Air Cleaning Equipment

FAA should investigate and publicly report on the need for and feasibility of installing air-cleaning equipment for removing particles and vapors from the air supplied by the ECS [environmental control system] on all aircraft to prevent or minimize the introduction of contaminants into the passenger cabin during ground operation, normal flight, and air quality incidents.

Response

NRC recommended that FAA investigate the need for particulate filters and gaseous filtration systems on all aircraft. FAA concurs with the intent of NRC's recommendation and is in the process of tasking an ARAC to review the existing standards and, if they are found to be inadequate, to propose new standards. The ARAC tasking directs its working group to review 14CFR Part 25, §§25.831(a) through (d) and 25.832, and to:

Evaluate the current transport category airworthiness regulations regarding the airplane environment to determine if revisions are needed to ensure that the ventilation systems provide a suitable environment for crew and passengers.

Assess the following issues:

- The appropriate filtration and monitoring mechanisms to provide suitable cabin air quality. Odors, chemical and biological contaminants (bio-aerosols), particulates, and other contaminants should be included in the review to ensure that sufficient design safeguards exist such that any contaminants present do not reach a concentration which would impact crew performance, disable any passenger, or create long term health problems in passengers or crew.

Without attempting to predict the outcome of the ARAC review, FAA anticipates that the regulations governing airplane air quality may evolve into a more comprehensive standard based on applicable parts of an existing consensus standard for environmental health that includes a maximum level of particulate and gaseous contaminants.

Discussion

Section 25.831 established standards for the quantity of fresh air to be provided per occupant of an airplane cabin and the maximum amount of carbon dioxide and carbon monoxide gas that can be present. Section 25.832 established the maximum amount of ozone that can be present. Section 25.841 established standards for the pressurized compartments in all transport category airplanes. None of these regulations require the airplane manufacturer to incorporate a particulate filtration system or gaseous adsorption system into the environmental control system.

Manufacturers of most new airplanes incorporate either High Efficiency Particulate Air (HEPA) filters (rated at 99.97% removal efficiency for 0.3 µm particles) or particulate filters that are somewhat less efficient (rated at 97-99.5% removal efficiency for 0.3 µm particles) at the request of their customers. Several airlines have installed HEPA filters on board airplanes that did not originally incorporate them in their design. Others are experimenting with the use of gaseous

adsorption systems onboard large commercial airplanes, but no large transport category airplane is routinely manufactured with these systems installed.

NRC Recommendation 4 – Carbon Monoxide Monitoring

FAA should require a CO monitor in the air supply ducts to passenger cabins and establish standard operating procedures for responding to elevated CO concentrations.

Response

NRC recommended that FAA mandate the installation of a CO (carbon monoxide) monitoring system and that it establish flight crew procedures for responding to elevated CO. The text of its report included four related recommendations that suggest that NRC envisioned a more comprehensive air quality monitoring system:

- Because CO is most likely produced during air quality incidents involving leaks of engine lubricating oils or hydraulic fluids in the ECS, it should be monitored in the ducts that introduce air into the cabin or cockpit.
- More research should be conducted to determine products that might be generated when engine lubricating oils, hydraulic fluids, and deicing fluids are exposed to high temperatures that might be encountered in the ECS.
- Instruments for monitoring O₃, CO, and CO₂, temperature, cabin pressure, relative humidity, and particulate material (PM) should be used in the surveillance or research investigations aboard commercial aircraft as described in Chapter 8 (of the NRC report).
- Routine surveillance of a number of air quality characteristics (O₃, CO and CO₂, fine PM, cabin pressure, relative humidity and temperature) should be implemented in a continuing program to characterize the range of air quality found in aircraft.

As noted in the response to NRC's Recommendation 1, FAA supports the development of a system that would alert the crew to the presence of an air contaminant. It also agrees that research is needed regarding the products of pyrolysis associated with hydraulic fluids, engine oils, and lubricants. The need for monitoring for the air quality characteristics noted above may result from the research initiatives outlined in the response to NRC's Recommendations 9 and 10. For FAA, the flight crew's response to an "air contaminant" event is a more important concern than CO monitoring. It envisions a system that will ensure that the flight crew is aware of an "air contaminant" event and will identify the source. FAA concurs with the need for a warning and it communicated this to NRC during its study. However, CO may not be the correct or the only contaminant to "trigger" on.

As noted above, FAA is tasking an ARAC to review the existing standards and, if they are found to be inadequate, to propose new standards. The ARAC tasking directs its working group to review 14CFR Part 25, §§25.831(a) through (d) and 25.832, and to:

Evaluate the current transport category airworthiness regulations regarding the airplane environment to determine if revisions are needed to ensure that the ventilation systems provide a suitable environment for crew and passengers.

Assess the following issues:

- The appropriate filtration and monitoring mechanisms to provide suitable cabin air quality. Odors, chemical and biological contaminants (bio-aerosols), particulates and other contaminants should be included in the review to ensure that sufficient design safeguards exist such that any contaminants present do not reach a concentration which would impact crew performance, disable any passenger, or create long term health problems in passengers or crew.

While it would be inappropriate to predict the outcome of the ARAC's deliberations, FAA believes that the regulations governing airplane air quality will evolve into the adoption of a requirement that the airplane be designed with features which enable the flight deck crewmembers to successfully isolate system failures. Such a system would discriminate between "normal" and "abnormal" levels of certain types of gaseous agents, chemicals and bioaerosols. It may be feasible to incorporate a dual monitoring system that continuously measures background levels as well as the unusual "spikes" that indicate the presence of a contaminant. However some contaminant hazards may require unique monitoring instruments.

Discussion

The existing Federal Aviation Regulations governing the cabin environment onboard large transport category airplanes are contained in 14CFR §§25.831, 25.832, and 25.841.

Section 25.831 intends that passengers and crewmembers have enough uncontaminated air to provide reasonable comfort during normal operating conditions and also after any probable failure (i.e. failure conditions with a probability of 1×10^{-5} or greater) of any system that would adversely affect the cockpit or cabin ventilation air. FAA's interpretation of the regulation has always been restricted to compliance with ventilation, CO or CO₂. There is no requirement for the presence of a system to monitor cabin "air quality" (i.e., O₃, CO and CO₂, temperature, cabin pressure, relative humidity, and particulate material, as discussed by NRC).

Available data do not suggest that a continuously operated air quality monitoring system will add significant benefit for passengers and crews, especially relative to the added cost. As communicated to NRC, FAA has never required an air quality monitoring system that provides a warning to the crew that an air contaminant is present. FAA's internal review has shown that air quality events or failures that impact cabin air quality are highly improbable (i.e., between 10^{-5} and 10^{-7}). FAA is searching its databases to determine the number of air contaminant events.

However, there have been a number of serious incidents in Australia, Europe and Canada in which pilots have become incapacitated during a flight because of suspected air contaminants. It is not clear whether a CO monitor would have been sufficient to detect the presence of the contaminant. FAA believes that there may be other chemicals or a broader set of hazards, including biohazards, that should be monitored. FAA is aware that some manufacturers are pursuing the development of bleed air monitors to provide real-time notification of the presence of air contaminants to the flight crew to enable enhanced failure isolation procedures. Currently, no large transport category airplane is routinely manufactured with these systems installed.

FAA is aware that several airlines are experimenting with the use of gaseous adsorption for some types and quantities of contaminants. Gaseous adsorption would fail to provide protection for massive quantities of contaminants. Currently, no large transport category airplane is routinely manufactured with these systems installed.

All existing commercial transport category airplanes have procedures in their airplane flight manuals to follow in the event of smoke or an unknown contaminant or smell in the cockpit. These typically require the flight crew to don oxygen masks and attempt to isolate the source. However, currently, no commercial transport category airplane incorporates a monitoring system that informs the crew when an air contaminant is present or enables the flight deck crewmembers to know the exact location of the contaminant's introduction into the system. As noted above, the issue of air contaminant isolation will be included in FAA rulemaking activities.

NRC Recommendation 5 – Allergens

Because of the potential for serious health effects related to exposures of sensitive people to allergens, the need to prohibit transport of small animals in aircraft cabins should be investigated, and cabin crews should be trained to recognize and respond to severe, potentially life-threatening responses (e.g., anaphylaxis, severe asthma attacks) that hypersensitive people might experience because of exposure to airborne allergens.

Response

NRC, in response to concerns about health risks to airline passengers who are sensitive to allergens, recommended an investigation to determine if small animals should be prohibited in airplane cabins. It also recommended that cabin crews be trained to recognize and respond to severe reactions to airborne allergens.

Allergens in the airplane cabin are a serious, potentially life-threatening, issue for a small segment of the airline passenger population. FAA will take several actions to address this area of concern. It will issue an Advisory Circular that incorporates the most effective industry practices regarding passenger handling procedures for allergen-sensitive people seated close to animals. The circular also will address the importance of crewmember training in recognizing and responding to in-flight medical events that result from allergen exposure.

In addition, every effort will be made to ensure that flight attendants and the aviation community in general have the most up to date information for the treatment of allergen-related medical events. This information will complement existing FAA regulations and guidance specific to flight attendant training regarding the response to severe allergic reactions. FAA guidance on this area of flight attendant training is also contained in Advisory Circular 120-44A, Air Carrier First Aid Programs.

Vehicles for disseminating information on allergen related events would include:

- FAA's Civil Aerospace Medical Institute (CAMI) Cabin Safety Workshop for flight attendants
- A CAMI web site that will be established (see the response to NRC's Recommendation 6, below)
- The Department of Transportation (DOT), Aviation Consumer Protection Division's web site that provides safety and security information
- The Flight Standards Service web site

Information currently provided on DOT and FAA web sites about pets and service animals will be enhanced to include FAA policy on the carriage of animals in the cabin, the policies of air carriers, including those that do not allow animals in the cabin, and additional sources of consumer information.

As part of the surveillance and research efforts described in Recommendations 8 and 9, the data collection forms now used in the in-flight medical event program will be evaluated to ensure optimum coverage of allergen-related medical problems. The program also will be enhanced to include as many airlines as possible.

Responding to allergen-related medical events such as anaphylaxis and asthma attacks may require the use of the regulatory-mandated in-flight emergency medical kit. FAA published a final rule on Emergency Medical Equipment on April 12, 2001 which required automated external defibrillators on large passenger-carrying aircraft as well as enhancements to the emergency medical kits, including a bronchodilator inhaler and additional epinephrine. Under §21.805, crewmembers must receive instruction in emergency medical event procedures as well as instruction that will familiarize them with the contents of the emergency medical kit.

With regard to NRC's recommendation regarding the prohibition of animals in the cabin, FAA does not believe a regulatory action in this area is warranted. Currently, air carriers formulate their own policies and procedures pertaining to animals in the cabin. The Air Carrier Access Act (ACAA)⁵ rules require that dogs and other service animals be allowed to accompany passengers with disabilities in the airline cabin. Prohibiting animals will not completely eliminate the exposure of sensitive passengers to allergens introduced from other sources, including passenger clothing, in the cabin environment. Animal dander typically remains localized near the animal for the duration of the flight because of zonal airflow within the cabin and the industry's increasing use of HEPA filters in the cabin ventilation systems.

Discussion

A review of the major airlines found that they all have procedures related to the carriage of animals in the cabin and that existing procedures are fairly standard among air carriers. Conditions of acceptance of animals in the cabin typically include:

- A list of animals that would be accepted for transport
- A limit on the number of animals in the cabin
- A limit on the number of animals that may accompany one passenger
- A requirement that the animal be harmless, inoffensive and odorless
- A requirement that the animal be confined in a container or cage that fits completely under the seat
- A requirement that the passenger be able to produce a health certificate issued within 30 days of originating travel

Typical flight attendant procedures to address passenger concern include reseating the passenger with the animal away from an allergen-sensitive passenger or coordinating with customer service personnel to offer another flight to the passenger with the animal. At present, one major airline does not accept animals for transportation in the aircraft cabin, except for service animals trained to assist persons with disabilities. Present FAA regulations⁶ and guidance specific to flight

⁵ See Appendix for partial text

⁶ See Appendix 1, §121.805 – Crewmember Training for In-flight Medical Events

attendant training address recognition and response to the severe allergic reactions that hypersensitive passengers might experience because of the presence of allergens on the aircraft.

The literature reviewed in NRC's report supports its concern about animal allergens in airliner cabins. However, another recent study⁷ found that, although dog and cat allergens were present in public transportation vehicles at levels that can cause symptoms in sensitive persons, prohibiting them probably would bring only a modest reduction in allergen levels because much of the allergen contamination that is present in the aircraft cabin is carried in on the clothes of other passengers.

Additional information is available from the CAMI through its collaboration with Medaire®, an industry provider of in-flight medical support. A study⁸ based on 1996-97 data on passenger and crew medical events that resulted in a call to Medaire for support covered about 20% of U.S. airline passengers. The study showed that 2.4% of the in-flight medical events were allergic events. There were no deaths in this category of in-flight medical events and no mention of animals in the cabin. The data are from actual in-flight medical events and is not likely to have excluded serious cases of allergy. If the study is repeated in the future, it will benefit from a much larger (~50%) level of airline industry participation.

The Allergy and Respiratory categories were searched to evaluate the past history of reported problems with allergens. When searched for allergy, no cases specifically mentioned animals as the cause of the allergic reaction. Specific mention was made of shellfish (2), insect bite (1), peanut allergic reaction (1), egg allergic reaction (1), drug reaction (1), and allergy shot reaction (1).

In the Allergy data set (n=27), the emergency medical kit was used about half the time (13 out of 27 events). Oxygen was used in 4 of the 27 events. In the Respiratory data set (n=92), 8 of the 92 events were identified as asthma. No cases specifically mentioned animal allergy as the cause of the respiratory condition and no deaths were reported. The Respiratory data set included one case of a passenger who choked on a peanut, but not due to allergy.

The emergency medical kit was not used in 48 of the 92 events; it was used in 39; its use was not specified in 5. Oxygen was used 83 of the 92 events (90%). Epinephrine was used 1 time in an asthma case listed in the respiratory category. Benzodiazepine was used 1 time. Bronchodilator was used in 14 of 92 events (15%). Oral antihistamine was used 2 times and injectable diphenhydramine was not used in any of the 92 events.

⁷ "Occurrence of Dog, Cat and Mite Allergens in Public Transport Vehicles"; Partti-Pellinen K., Marttila O., Makinen-Kiljunen S., Haahtela T. *Allergy* 55(1): 65-8, 2000.

⁸ Reported in DOT/FAA/AM-97/2 DeJohn, Véronneau, Hordinsky and DOT/FAA/AM-00/13 DeJohn, Véronneau, Wolbrink, Larcher

NRC Recommendation 6 – Health Information

Increased efforts should be made to provide cabin crew, passengers, and health professionals with information on health issues related to air travel. To that end, FAA and the airlines should work with such organizations as the American Medical Association and the Aerospace Medical Association to improve health professionals' awareness of the need to advise patients on the potential risks of flying, including risks associated with decreased cabin pressure, flying with active infections, increased susceptibility to infection or hypersensitivity.

Response

NRC recommended increased efforts to provide cabin crew, passengers, and health professionals with information on health issues related to air travel, and especially on the potential risks of flying. This effort should be a collaborative one that includes airlines and professional medical organizations such as the American Medical Association and the Aerospace Medical Association.

FAA concurs with NRC's recommendation and will continue to focus the attention of its Office of Aerospace Medicine on potential health issues and problems for healthy passengers, for passengers with a variety of medical problems, and for crewmembers. In addition, it will increase its efforts to make available information and recommendations on air travel health and medical issues through a web site that is accessible to the general public.

FAA's Office of Aerospace Medicine has established and will continue to enhance a readily accessible portion of the CAMI web site to provide appropriate health and medical information and recommendations that is as up-to-date as possible. This will include research findings and other information that becomes available as a result of activities that develop from NRC's Recommendations 8 and 9. Based on data from the surveillance and research programs, special groups such as young and elderly passengers and patient populations that have unique predisposition to problems in the civilian aviation environment would be identified and informed of the risks associated with air travel.

Discussion

The Aerospace Medical Association has developed general medical guidelines for passengers in civilian aviation. The American College of Obstetricians and Gynecologists Committee on Obstetric Practice recently developed and published recommendations concerning air travel during pregnancy⁹. Similar recommendations from other medical specialties should be readily available and accessible in the up-to-date form to all medical professionals, aviation passengers and crewmembers, and the general public.

CAMI conducts seminars and other training activities for Aviation Medical Examiners (AMEs) that include discussion of health issues in civil aviation operations. The AME courses are oriented to the professional health care provider and medical certification of airmen and provide an opportunity to communicate with over 4,500 health care providers. These professionals

⁹ Obstet. Gynecol. 2001; 98:1187-1188

represent a significant asset for providing health-related information to aviators and the flying public. CAMI produces aeromedical publications that, in the future, will include coverage of more health issues. New educational outreach activities and instructional tools (such as brochures, videos, and web page information) will be developed by the Aeromedical Education Division at CAMI to provide cabin crew, passengers, and health care providers with information regarding health issues in civil aviation. Adequate distribution of the material will depend on the availability of additional resources.

In addition to the seminars and training for AMEs, the CAMI Aeromedical Education Division provides courses in aviation physiology and global survival. These training programs for aviation professionals may be used as a conduit for passenger and cabin safety information. The CAMI Aeromedical Education Division also provides seminars and demonstrations at numerous air-shows and aviation-related events. While these events are generally attended by aviation professionals and general aviation pilots and owners, information on passenger and cabin safety that is of interest to the general public is also disseminated. The CAMI Aeromedical Research Division conducts a Cabin Safety Workshop that is oriented toward cabin safety and flight attendant issues. The workshop provides current information and practical training on cabin evacuation, biodynamics, altitude, recent accidents and general cabin safety information. These training programs transmit information to the flying public both directly and indirectly.

As noted above, DOT's Aviation Consumer Protection Division maintains a web site that provides safety and security information and acts as a focal point for consumer problems and complaints. The Assistant Secretary for Transportation Policy maintains a web site on smoking and disinsection policies of airlines and countries. The Office of the Secretary of Transportation and FAA provide information regarding traveling with animals or service animals and guidance for passengers with special travel requirements (oxygen bottles, wheel chairs, other support needs).

NRC Recommendation 7 – Ventilation Shutdown

The committee reiterates the recommendation of the 1986 NRC report that a regulation be established to require removal of passengers from an aircraft within 30 minutes after a ventilation failure or shutdown on the ground and to ensure the maintenance of full ventilation whenever on-board or ground-based air conditioning is available.

Response

NRC repeated its 1986 recommendation that a regulation be established to require air carriers to remove all passengers from an aircraft within 30 minutes after a ventilation failure or shutdown on the ground and also require air carriers to use full ventilation on the ground whenever on-board or ground-based air conditioning is available.

FAA concurs with the objective of the recommendation. It will issue an Advisory Circular to expand its guidance to all air carriers regarding the need to maintain full ventilation whenever onboard or ground air-conditioning is available and the need to deplane passengers within 30 minutes after a ventilation failure or shutdown on the ground, when possible.

This guidance will include a statement of the problem, background information, and a discussion of all relevant issues and operational considerations that may impact an air carrier's decision to deplane passengers. NRC's recommendation was based on a concern about the spread of disease among passengers when forced air ventilation is not available on the ground. However, FAA also is aware that there may be other issues, including safety, job performance, and comfort of passengers and crewmembers who are required to remain onboard an aircraft on the ground during a ventilation failure or shutdown.

Discussion

The original recommendation in the 1986 NRC report was based on information regarding a 1977 outbreak of influenza among passengers and crew exposed to a passenger in the early stages of influenza. The aircraft was on the ground for several hours undergoing maintenance and the ventilation system was inoperative while repairs were attempted. The passengers who were onboard the aircraft were given a choice whether to remain onboard or return to the terminal. Of those passengers who elected to remain onboard, which included the passenger with influenza, a majority was inflicted with influenza in varying degrees of severity within a few days. None of the passengers who elected to wait in the terminal and then continue the flight on a substitute, normally ventilated aircraft, contracted influenza.

NRC concluded that proper operation of the air circulation equipment might have prevented the outbreak of influenza. It recommended in 1986 and again in 2001 that, during passenger operations, when ventilation could not be maintained on any aircraft on the ground, all passengers must be deplaned within 30 minutes or less from ventilation failure or shut down.

The 1986 NRC recommendation was as follows:

Because a likelihood of occurrence of epidemic disease when forced air ventilation is not available on the ground has been demonstrated, the Committee recommends that a regulation be established that requires removal of passengers from an airplane within 30 minutes or less after a ventilation failure or shutdown on the ground and maintenance of full ventilation whenever onboard or ground air-conditioning is available.

The response to this recommendation stated in part:

DOT agrees that confinement in an unventilated enclosure (room, car, bus, etc.) will facilitate spread of epidemic disease. Because the occurrence of complete ventilation cessation on passenger-laden airplanes is extremely rare.... we do not believe that regulatory action is necessary....

Planned Action

While the risk of occurrence of complete ventilation cessation on passenger-laden airplanes is extremely low, we believe that there may be value in bringing this concern to the attention of the air carriers. FAA will advise air carriers of the need to deplane passengers, if possible, after thirty minutes without ventilation.

An Action Notice to FAA Inspectors on "Passenger Handling During Ground Operations with No Cabin Ventilation" was issued on October 19, 1987 and was in effect through October 1988. In the Action Notice and its 1987 response to Congress, FAA interpreted NRC's recommendation to require removal of all passengers, if possible, after thirty minutes without ventilation. FAA's current understanding of the recommendation, based on clarifying information in NRC's report, is that the removal of passengers from an airplane must be completed within 30 minutes after a ventilation failure or shutdown on the ground.

NRC Recommendation 8 – Surveillance Program

To be consistent with FAA's mission to promote aviation safety, an air quality and health surveillance program should be established. The objectives and approaches of this program are summarized in Table S-2. The health and air quality components should be coordinated so that the data are collected in a manner that allows analysis of the suggested relationship between health effects or complaints and cabin air quality.

Table S-2 Surveillance and Research Programs

Surveillance Program Objectives

- *To determine aircraft compliance with existing FAR's for air quality*
- *To characterize accurately air quality and establish temporal trends of air quality characteristics in a broad sample of representative aircraft*
- *To estimate the frequency of non-routine operations in which serious degradation of cabin air quality occurs*
- *To document systematically health effects or complaints of passengers and crew related to routine conditions of flight or air quality incidents; to be effective, this effort must be conducted and coordinated in conjunction with air quality monitoring*

Surveillance Program Approach

- *Continuously monitor and record O₃, CO, CO₂, fine particles, cabin pressure, temperature, and relative humidity*
- *Sample a representative number of flights over a period of 1-2 years*
- *Continue to monitor flights to ensure accurate characterization of air quality as new aircraft come online and aircraft equipment ages or is upgraded*
- *Conduct a program for the systematic collection, analysis, and reporting of health data with the cabin crew as the primary study group*

Response

NRC recommended that FAA establish a surveillance program for both air quality and health. The program's objectives and approaches are summarized in Table S-2, Surveillance and Research Programs. The components of the surveillance program are to be coordinated so that the data collected allows analysis of the suggested relationship between health effects or complaints and cabin air quality. The proposed air quality and health surveillance is to be linked closely to NRC's Recommendation 9 that covers a broad range of potential research efforts. Data gathered from the proposed surveillance effort could be used to help define the scope of the research effort. FAA concurs with the intent of NRC's recommendation.

NRC's report correctly linked its research proposal with a health effects survey effort and suggested that they both should be addressed by the agency that is designated to lead the research project. NRC proposed that the NIOSH air sampling and health effects survey projects be reviewed to determine their applicability to the proposed research effort. The NIOSH effort has developed the sampling capability and survey procedures to conduct a preliminary study. Similarly, the lead research organization should review all available data to develop procedures that could accurately define the frequency of non-routine air quality incidents and determine if

and what after-the-fact investigation procedures could be implemented. Combined government, industry, and union participation will be critical to the success for the effort.

Discussion

As required by FAA Authorization Act,¹⁰ FAA contracted with the Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH) to conduct a study to characterize and identify potential health issues related to the aircraft cabin environment. A preliminary study established a surveillance program to continuously monitor and record seven cabin air quality parameters: ozone (O₃), carbon monoxide (CO), carbon dioxide (CO₂), fine particles that are less than 10 micrometers in diameter (PM₁₀), cabin atmospheric pressures, dry bulb temperatures, and relative humidity. These and additional parameters were monitored by NIOSH over two years on 33 commercial flights on ten different types of airplanes owned by four air carriers. NIOSH was also directed to conduct a health effects survey of female flight attendants that initially focused on reproductive health, and was later expanded to include respiratory effects. The respiratory effects survey included a generally non-flying comparison group of teachers. The study addresses respiratory symptomatology (both infectious and noninfectious etiology), flight history data, and lifestyle factors. The study did not include direct linkage to measurement of cabin environment conditions. The survey respondents flew on a wide variety of aircraft in which the cabin environment was not sampled.

The process established in this research effort provides a starting point for the development of a longer-term surveillance and health effects assessment that could meet some of NRC's recommendations for routine flights. With the cooperation and coordination of the airlines, flight attendants and other parties, a health effects survey could be used on a small number of monitored flights (NRC's report suggests 100 flights) to support linkage of air quality sampling and comfort and health effects.

Surveillance to identify the potential cabin air contaminants and their potential health effects during non-routine, air quality system events is a more complex and difficult issue. As part of the surveillance program, NRC suggests that methods be developed or utilized to estimate the frequency of non-routine operations in which serious degradation of cabin air quality occurs. As discussed under Recommendation 1, available data suggest that air quality system failures are extremely rare events. This was recognized by NRC's statement in Chapter 8 that sampling the number of flights necessary to gain valid air quality data during non-routine flights "is not feasible." Chapter 8 provided a number of suggestions on how to identify potential air quality incidents and establish a monitoring regimen. These suggestions include "ad-hoc" air sampling and a health effects survey or interview to be conducted following a potential air quality incident. FAA could provide some laboratory analytical support for the ad hoc sampling program. However, gathering data on-site and completing health effects surveys or interviews would require industry or other agency participation as would any medical follow up. The other NRC suggestions on how to isolate non-routine air quality events include review of aircraft maintenance records, focusing on "problem aircraft," analysis of contaminants in air filtration systems, and investigation of only aircraft or flights which have reported problems. Each of these areas will require further investigation by both government and industry to determine feasibility and potential effectiveness. It must be noted that while the identification of air quality

¹⁰ PL 103-305, §304

incidents and air sampling may be improved by a number of methods, the health effects information from surveys and interviews will remain primarily subjective.

NRC Recommendation 9 – Research Program

To answer specific questions about cabin air quality, a research program should be established (see Table S-2). The committee considers the following research questions to be of high priority:

- *O₃. How is the O₃ concentration in the cabin environment affected by various factors (e.g., ambient concentrations, reaction with surfaces, the presence and effectiveness of catalytic converters), and what is the relationship between cabin concentrations and health effects on cabin occupants?*
- *Cabin pressure and oxygen partial pressure. What is the effect of cabin pressure altitude on susceptible cabin occupants, including infants, pregnant women and people with cardiovascular disease?*
- *Outside-air ventilation. Does the ECS provide sufficient quantity and distribution of outside air to meet the FAA regulatory requirements (FAR 25.831), and to what extent is cabin ventilation associated with complaints from passengers and cabin crew? Can it be verified that infectious-disease agents are transmitted primarily between people in close proximity? Does recirculation of cabin air increase cabin occupants' risk of exposure?*
- *Air quality incidents. What is the toxicity of the constituents or degradation products of engine lubricating oils, hydraulic fluids, and deicing fluids, and is there a relationship between exposures to them and reported health effects on cabin crew? How are these oils, fluids, and degradation products distributed from the engines into the ECS and throughout the cabin environment?*
- *Pesticide exposure. What are the magnitudes of exposures to pesticides in aircraft cabins and what is the relationship between the exposures and reported symptoms?*
- *Relative humidity. What is the contribution of low relative humidity to the perception of dryness, and do other factors cause or contribute to the irritation associated with the dry cabin environment during flight?*

Table S-2, Surveillance and Research Programs

Research Program Objectives

- *To investigate possible association between specific air quality characteristics and health effects or complaints*
- *To evaluate the physical and chemical factors affecting specific air quality characteristics in aircraft cabins*
- *To determine whether FAR's for air quality are adequate to protect health and ensure comfort of passengers and crew*
- *To determine exposure to selected contaminants (e.g., constituents of engine lubricating oils and hydraulic fluids, their degradation products, and pesticides) and establish their potential toxicity more fully*

Research Program Approach

- *Use continuous monitoring data from surveillance program when possible*
- *Monitor additional air quality characteristics on selected flights as necessary (e.g., integrated particulate-matter sampling to assess exposure to selected contaminants)*
- *Identify and monitor “problem” aircraft and review maintenance and repair record to evaluate issues associated with air quality incidents*
- *Collect selected health data (e.g., pulse-oximetry data to assess arterial O₂ saturation of passengers and crew)*
- *Conduct laboratory and other ground-based studies to characterize air distribution and circulation and contaminant generation, transport, and degradation in the cabin and ECS*

Response

NRC’s report noted that existing air quality data are inadequate for evaluating the possible association between air contaminants and cabin environmental conditions during routine operations and the health problems and complaints from passengers or crewmembers. Data are also inadequate regarding the possible associations of cabin air quality and health effects for non-routine operations. As discussed in previous sections, data on accident and incident, pilot incapacitation, and Medair calls are available but reports seldom contain actual air sample contaminant data. To address these issues, NRC’s report proposed a combined surveillance and multifaceted research program addressing “Air-quality Surveillance, Health Surveillance, Air Quality Research, and Staging.” FAA concurs with the intent of this recommendation.

The NRC report is a well-documented assessment of the questions currently facing FAA and the aviation industry concerning transport aircraft air quality and health and comfort issues. While the report does not identify significant flight safety issues related to the cabin environment, these too deserve future research attention. To address these issues, the simplest step facing the researcher may be to develop sampling equipment and techniques to determine air quality. The most difficult step may be to accurately relate the cabin air quality to a given effect and to determine if the effect is health or simply comfort related. A combined effort by aviation officials (government, union, and industry) will be needed to develop and execute a successful research effort.

Discussion

Air Quality Surveillance. As mentioned in the discussion of Recommendation 8, FAA has initiated a cabin air quality monitoring effort through NIOSH. While this project has not included monitoring (33 flights during the last 2 years), sampling capability and procedures have been developed, and further monitoring will be conducted. NRC’s report suggested that an air quality surveillance program should conduct air sampling on a minimum of 100 flights. A modification and continuation of the NIOSH effort could meet this recommendation and provide initial air quality and health effects data to determine if more extensive efforts are required for routine flight conditions.

Health Surveillance. The NIOSH effort did conduct a health effects survey. This survey included a questionnaire for flight attendants and a comparison group of schoolteachers. The NIOSH study was partially successful in gathering questionnaire data. Currently the NIOSH

study is attempting to validate the questionnaire data through a follow-up review of actual medical data. NRC's report notes that to provide an effective cabin air quality assessment, both air samples and occupant health questionnaire data should be gathered from the same flight. The report also notes that the principal focus of the health questionnaire should be the flight attendants. While it is recognized that air quality in the cabin section of the aircraft could be different from the cockpit, the pilots are required to undergo frequent medical examinations and have significant medical documentation that could be used to establish preexisting conditions and validate questionnaire responses. Such information might not be available from the flight attendants and the researcher is faced with subjective health questionnaire data that may or may not be supported by medical information.

FAA gathers data from any reported pilot incapacitation and has data on failures of cabin pressure, smoke, or fumes in the aircraft or other major environmental control system failures. Additionally, FAA gathers information from in-flight or flight-related medical events that are reported through Medaire. While these reports are generally focused on flight safety issues, reports on any use of the in-flight emergency medical kit and the equipment/medications used are provided. The presence or absence of reported medical incidents might assist in developing a monitoring program to evaluate major health-related issues. FAA conducted an evaluation on the use of the Automated External Defibrillators (AEDs) carried onboard commercial aircraft in 1996-97. This evaluation provided in-flight medical information, but when the passenger was removed from the aircraft to a medical facility, tracking and gathering medical data became very difficult. Similar follow-up problems may be inherent in any in-flight health reporting system or assessment.

Air Quality Research. NRC's report identifies air quality research as separate from the surveillance programs but closely related. Areas specifically identified for more intensive research were ozone, cabin pressure and oxygen partial pressure, and outside air ventilation.

Ozone. From the data available, NRC's report concludes that CO and CO₂ concentrations generally do not appear to exceed FAA guidelines, although they may on occasion. Other sections of the report note that symptoms of ozone exposure are nonspecific and that common respiratory symptoms could be rightly or wrongly attributed to ozone exposure. In this proposed research area, the major emphasis appears to be the definition of ozone concentrations in various phases of flight, the interaction/reaction of ozone with cabin surfaces and the effectiveness of ozone converters in the aircraft. As discussed under the response to Recommendation 8, a preliminary sampling of a number of aircraft could help define the ozone concentration levels and, if aircraft with and without ozone converters are sampled, a preliminary finding on the effectiveness of ozone converters could be developed.

Cabin Pressure and Oxygen Partial Pressure. NRC's report suggested that cabin pressure equivalents of 8,000 feet could be hazardous for susceptible passengers, such as those with pulmonary or cardiovascular disease and infants). Headache and other symptoms of mild altitude sickness may occur in some healthy individuals at elevations below 8,000 feet, a phenomenon encountered not infrequently by physicians practicing in mountainous areas. NRC's report suggested that pulse oximetry techniques could be used in-flight to monitor hemoglobin saturation in the passengers and crew.

NRC documented a significant literature in this area. However, the majority of the research has been conducted on healthy individuals in appropriate research facilities. An evaluation of the effect of altitude on susceptible individuals would require significant medical evaluation to determine the extent of their disability and to relate this disability to arterial oxygen levels. These procedures would not be possible in a flight environment. An in-depth review of current medical research should be conducted to determine if adequate information is available to better advise physicians and the flying public on medical fitness to fly questions. As emphasized in Recommendation 6, education of health professionals, aircrew, and the flying population is an important flight safety concern.

Outside Air Ventilation. Comments on Recommendation 1 address FAA certification requirements for airflow in the passenger compartment of a transport aircraft. The adequacy of these requirements and general questions regarding bioaerosol transmission in the aircraft are being studied at several levels. The NIOSH cabin environment research effort includes a study of in-flight disease transmission. An environmental chamber and a Computational Fluid Dynamics (CFD) model were developed to measure and track particles emitted during physiological maneuvers (speaking, coughing, and sneezing). Additionally, the NIOSH study contracted with a major aircraft manufacturer to develop a model of airflow within a transport aircraft cabin to determine airflow pattern of bioaerosols. In a separate effort, CAMI started development of a CFD model to evaluate the potential spread of biological or chemical weapons materials in an aircraft. This study is using airflow data gathered from their Boeing 747 cabin environment simulator to support the modeling effort.

Air Quality Incidents. In Chapter 8 of its report, NRC noted that gathering cabin air quality and health effects data during infrequently occurring air quality incidents is a difficult issue. The report correctly observes that air handling system failures are an infrequent event and accurate sampling of induced contaminants would require monitoring thousands of flights. The report suggests that the task of gathering samples during air quality incidents could be made less daunting by using aircraft maintenance data to focus on specific aircraft or aircraft types. Obviously such use of aircraft maintenance information would support a monitoring effort; however, industry legal and operational concerns could affect the effort. FAA and industry knowledge of the frequency of air quality incidents would be improved by requiring crewmembers to report all such events. The issue of air quality incidents will be included in FAA rulemaking activities.

NRC Recommendation 10 – Research Program Lead Agency

The committee recommends that Congress designate a lead federal agency and provide sufficient funds to conduct or direct the research program proposed in recommendation 9, which is aimed at filling major knowledge gaps identified in this report. An independent advisory committee with appropriate scientific, medical, and engineering expertise should be formed to oversee the research program to ensure that its objectives are met and the results publically disseminated.

Response

NRC recommended the Congressional designation and funding of a research program with an independent advisory committee. FAA concurs with the recommendation and recommends that FAA be designated as the lead federal agency for the air quality research program and that sufficient additional funding be appropriated to accomplish NRC's recommended environmental monitoring, data collection, and research initiatives. FAA also proposes to include the research needs related to biological and chemical terrorism on board aircraft with those related to air quality. To this end, the FAA Administrator will recommend to the Secretary of Transportation that a cooperative effort with the Transportation Security Administration (TSA) be initiated to place sensor devices on U. S. air carrier aircraft. The devices would monitor airliner cabin air quality and detect biological and chemical contamination of cabin air in a manner that warns the aircrew and locates the source of contamination.

Discussion

The cooperative effort described above will address the air quality concerns of the flying public as well as the concerns of crewmembers and will provide a preemptive level of security against biological and biochemical attack recommended by national scientific experts knowledgeable in this area. Through this approach, the Administrator will implement NRC's recommendations relative to environmental monitoring and data collection and other research activities.

The Administrator will request Congress provide additional funding to support FAA initiatives addressed in this response. The request will include funds to support research for the cabin air monitoring and data collection as well as the research initiatives recommended by NRC.

The Administrator will implement the cabin air monitoring, data collection and other research initiatives through collaboration with research and standardization organizations.

Appendix 1 – Regulations and Related Material Cited in the Report

14CFR Part 25, §25.831 - Ventilation

(a) Under normal operating conditions and in the event of any probable failure conditions of any system which would adversely affect the ventilating air, the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort. For normal operating conditions, the ventilation system must be designed to provide each occupant with an airflow containing at least 0.55 pounds of fresh air per minute.

(b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapors. In meeting this requirement, the following apply:

(1) Carbon monoxide concentrations in excess of 1 part in 20,000 parts of air are considered hazardous. For test purposes, any acceptable carbon monoxide detection method may be used.

(2) Carbon dioxide concentration during flight must be shown not to exceed 0.5 percent by volume (sea level equivalent) in compartments normally occupied by passengers or crewmembers.

(c) There must be provisions made to ensure that the conditions prescribed in paragraph (b) of this section are met after reasonably probable failures or malfunctioning of the ventilating, heating, pressurization, or other systems and equipment.

(d) If accumulation of hazardous quantities of smoke in the cockpit area is reasonably probable, smoke evacuation must be readily accomplished, starting with full pressurization and without depressurizing beyond safe limits.

(e) Except as provided in paragraph (f) of this section, means must be provided to enable the occupants of the following compartments and areas to control the temperature and quantity of ventilating air supplied to their compartment or area independently of the temperature and quantity of air supplied to other compartments and areas:

(1) The flight crew compartment.

(2) Crewmember compartments and areas other than the flight crew compartment unless the crewmember compartment or area is ventilated by air interchange with other compartments or areas under all operating conditions.

(f) Means to enable the flight crew to control the temperature and quantity of ventilating air supplied to the flight crew compartment independently of the temperature and quantity of ventilating air supplied to other compartments are not required if all of the following conditions are met:

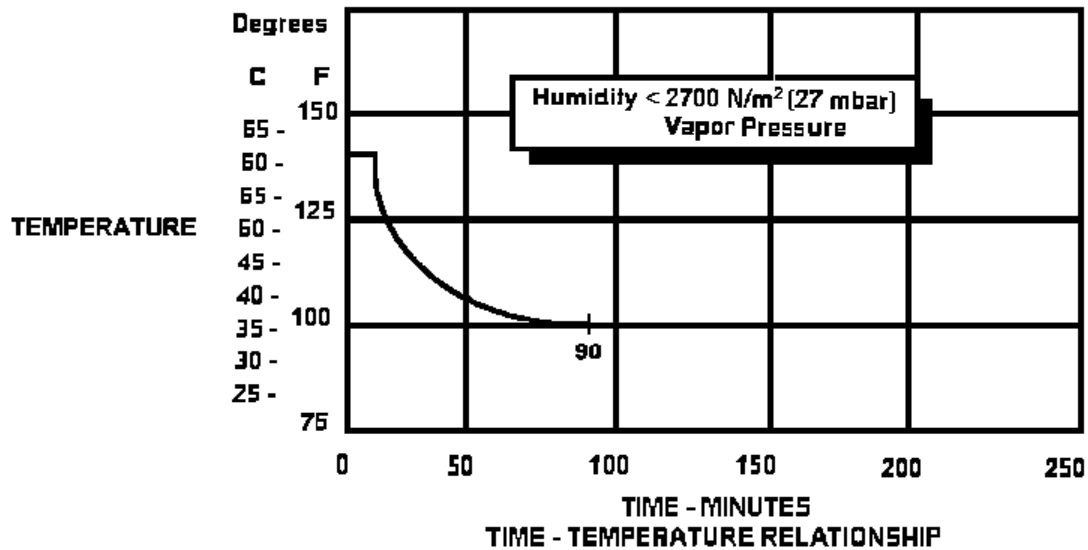
(1) The total volume of the flight crew and passenger compartments is 800 cubic feet or less.

(2) The air inlets and passages for air to flow between flight crew and passenger compartments are arranged to provide compartment temperatures within 5 degrees F. of each other and adequate ventilation to occupants in both compartments.

(3) The temperature and ventilation controls are accessible to the flight crew.

(g) The exposure time at any given temperature must not exceed the values shown in the following graph after any improbable failure condition.

Temperature curve from Amdt. 25-87



[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-41, 42 FR 36970, Jul. 18, 1977; Amdt. 25-87, 61 FR 28695, Jun. 5, 1996; Amdt. 25-89, 61 FR 63956, Dec. 2, 1996]

14CFR Part 25, §25.832 - Cabin Ozone Concentration

- (a) The airplane cabin ozone concentration during flight must be shown not to exceed-
 - (1) 0.25 parts per million by volume, sea level equivalent, at any time above flight level 320; and
 - (2) 0.10 parts per million by volume, sea level equivalent, time-weighted average during any 3-hour interval above flight level 270.
 - (b) For the purpose of this section, "sea level equivalent" refers to conditions of 25° C and 760 millimeters of mercury pressure.
 - (c) Compliance with this section must be shown by analysis or tests based on airplane operational procedures and performance limitations, that demonstrate that either-
 - (1) The airplane cannot be operated at an altitude which would result in cabin ozone concentrations exceeding the limits prescribed by paragraph (a) of this section; or
 - (2) The airplane ventilation system, including any ozone control equipment, will maintain cabin ozone concentrations at or below the limits prescribed by paragraph (a) of this section.
- [Amdt. 25-50, 45 FR 3883, Jan. 1, 1980, as amended by Amdt. 25-56, 47 FR 58489, Dec. 30, 1982]

14CFR Part 121, §121.578 - Cabin Ozone Concentration

- (a) For the purpose of this section, the following definitions apply:
- (1) "Flight segment" means scheduled nonstop flight time between two airports.
 - (2) "Sea level equivalent" refers to conditions of 25°C and 760 millimeters of mercury pressure.
- (b) Except as provided in paragraphs (d) and (e) of this section, no certificate holder may operate an airplane above the following flight levels unless it is successfully demonstrated to the Administrator that the concentration of ozone inside the cabin will not exceed:
- (1) For flight above flight level 320, 0.25 parts per million by volume, sea level equivalent, at any time above that flight level; and
 - (2) For flight above flight level 270, 0.1 parts per million by volume, sea level equivalent, time-weighted average for each flight segment that exceeds 4 hours and includes flight above that flight level (For this purpose, the amount of ozone below flight level 180 is considered to be zero).
- (c) Compliance with this section must be shown by analysis or tests, based on either airplane operational procedures and performance limitations or the certificate holder's operations. The analysis or tests must show either of the following:
- (1) Atmospheric ozone statistics indicate, with a statistical confidence of at least 84%, that at the altitudes and locations at which the airplane will be operated cabin ozone concentrations will not exceed the limits prescribed by paragraph (b) of this section.
 - (2) The airplane ventilation system including any ozone control equipment, will maintain cabin ozone concentrations at or below the limits prescribed by paragraph (b) of this section.
- (d) A certificate holder may obtain an authorization to deviate from the requirements of paragraph (b) of this section, by an amendment to its operations specifications, if:
- (1) It shows that due to circumstances beyond its control or to unreasonable economic burden it cannot comply for a specified period of time; and
 - (2) It has submitted a plan acceptable to the Administrator to effect compliance to the extent possible.
- (e) A certificate holder need not comply with the requirements of paragraph (b) of this section for an aircraft:
- (1) When the only persons carried are flight crewmembers and persons listed in Sec. 121.583;
 - (2) If the aircraft is scheduled for retirement before January 1, 1985; or
 - (3) If the aircraft is scheduled for re-engining under the provisions of Subpart E of Part 91, until it is re-engined.

[Doc. No. 121-154, 45 FR 3883, Jan. 21, 1980. Redesignated by Amdt. 121-162, 45 FR 46739, July 10, 1980; Amdt. 121-181, 47 FR 58489, Dec. 30, 1982; Amdt. 121-251, 60 FR 65935, Dec. 20, 1995]

14CFR Part 25, §25.841 - Pressurized Cabins

- (a) Pressurized cabins and compartments to be occupied must be equipped to provide a cabin pressure altitude of not more than 8,000 feet at the maximum operating altitude of the airplane under normal operating conditions.
 - (1) If certification for operation above 25,000 feet is requested, the airplane must be designed so that occupants will not be exposed to cabin pressure altitudes in excess of 15,000 feet after any probable failure condition in the pressurization system.
 - (2) The airplane must be designed so that occupants will not be exposed to a cabin pressure altitude that exceeds the following after decompression from any failure condition not shown to be extremely improbable:
 - (i) Twenty-five thousand (25,000) feet for more than 2 minutes; or
 - (ii) Forty thousand (40,000) feet for any duration.
 - (3) Fuselage structure, engine and system failures are to be considered in evaluating the cabin decompression.
- (b) Pressurized cabins must have at least the following valves, controls, and indicators for controlling cabin pressure:
 - (1) Two pressure relief valves to automatically limit the positive pressure differential to a predetermined value at the maximum rate of flow delivered by the pressure source. The combined capacity of the relief valves must be large enough so that the failure of any one valve would not cause an appreciable rise in the pressure differential. The pressure differential is positive when the internal pressure is greater than the external.
 - (2) Two reverse pressure differential relief valves (or their equivalents) to automatically prevent a negative pressure differential that would damage the structure. One valve is enough, however, if it is of a design that reasonably precludes its malfunctioning.
 - (3) A means by which the pressure differential can be rapidly equalized.
 - (4) An automatic or manual regulator for controlling the intake or exhaust airflow, or both, for maintaining the required internal pressures and airflow rates.
 - (5) Instruments at the pilot or flight engineer station to show the pressure differential, the cabin pressure altitude, and the rate of change of the cabin pressure altitude.
 - (6) Warning indication at the pilot or flight engineer station to indicate when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 10,000 feet.
 - (7) A warning placard at the pilot or flight engineer station if the structure is not designed for pressure differentials up to the maximum relief valve setting in combination with landing loads.
 - (8) The pressure sensors necessary to meet the requirements of paragraphs (b)(5) and (b)(6) of this section and 25.1447(c), must be located and the sensing system

designed so that, in the event of loss of cabin pressure in any passenger or crew compartment (including upper and lower lobe galleys), the warning and automatic presentation devices, required by those provisions, will be actuated without any delay that would significantly increase the hazards resulting from decompression. [Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-38, 41 FR 55466, Dec. 20, 1976; Amdt. 25-87, 61 FR 28696, Jun. 5, 1996]

14CFR Part 21, §21.805 - Crewmember Training for In-flight Medical Events

- (a) Each training program must provide the instruction set forth in this section with respect to each airplane type, model, and configuration, each required crewmember, and each kind of operation conducted, insofar as appropriate for each crewmember and the certificate holder.
- (b) Training must provide the following:
 - (1) Instruction in emergency medical event procedures, including coordination among crewmembers.
 - (2) Instruction in the location, function, and intended operation of emergency medical equipment.
 - (3) Instruction to familiarize crewmembers with the content of the emergency medical kit.
 - (4) Instruction to familiarize crewmembers with the content of the emergency medical kit as modified on April 12, 2004.
 - (5) For each flight attendant --
 - (i) Instruction, to include performance drills, in the proper use of automated external defibrillators.
 - (ii) Instruction, to include performance drills, in cardiopulmonary resuscitation.
 - (iii) Recurrent training, to include performance drills, in the proper use of an automated external defibrillator and in cardiopulmonary resuscitation at least once every 24 months.
- (c) The crewmember instruction, performance drills, and recurrent training required under this section are not required to be equivalent to the expert level of proficiency attained by professional emergency medical personnel.

The Air Carrier Access Act (ACAA) Rules

Carriers shall permit dogs and other service animals used by individuals with disabilities to accompany the person on a flight.

- (1) Carriers shall accept as evidence that an animal is a service animal identification cards, other written documentation, presence of harnesses or markings on harnesses, tags or the credible verbal assurances of the qualified individual with disabilities using the animal.

(2) Carriers shall permit a service animal to accompany a qualified individual with disabilities in any seat in which the person sits, unless the animal obstructs an aisle or other area that must remain unobstructed in order to facilitate an emergency evacuation.

FAA Advisory Circular 120-44A

The Handling of Illness and Injury. An air carrier's first aid program should provide information about protection of crewmembers from bloodborne pathogens (including use of barrier gloves), familiarization with the contents of the medical kit and the assessment of the severity and possible treatment of the medical problems listed below. This list also provides suggestions pertinent to some problems. However, neither the list nor the suggestions are all inclusive. Each air carrier should develop first aid programs that are appropriate to that air carrier's operations, equipment, and personnel. These programs should include information on the following:

(1) History and Assessment of individuals who are ill or injured. This information should be communicated to the flight crewmembers, any on-board medical assistants, and anyone offering medical assistance to the flight from the ground, and should be given to medical personnel who meet the flight....

(4) Shock, Unconsciousness, Major Allergic Response....

d. Assistance.

(1) From Persons on Board. Each first aid program should provide a procedure for identifying medically qualified persons on board the aircraft. These procedures should list those persons who would be considered medically qualified. For example, medical doctors, nurses, emergency medical technicians, or first aid instructors could be listed.

(2) From Persons on the Ground. Many airlines have procedures which allow crewmembers on board the flight to consult with medical personnel on the ground. This practice is highly desirable. Air carrier manuals and training should provide guidelines to crewmembers about obtaining medical consultation from the ground. The information obtained through the medical history and assessment should be passed on to these medical personnel.

The Aviation Safety Inspectors Handbook, Order 8400.10, Volume 3, Chapter 14, Section 4

Illness or Injury

General principles of Care: Effects of aircraft environment, crew medical responsibilities, crew coordination, including flight crew coordination, requesting and verification of medically qualified personnel, rules for administering medication, documentation and written reports, use of ground-to-air assistance, removal of ill or injured passengers.

In-flight Medical Emergencies/Incidents: Illness or injury symptom recognition and examination, attempt to obtain medical history, assessment of passenger, appropriate medical treatments, handling of passenger, aircraft limitations, crewmember incapacitation, apparent death, review of contents and use of first aid equipment

Appendix 2 – Abbreviations and Acronyms Used in the Report

ACAA:	Air Carrier Access Act
AED:	Automated External Defibrillators
AFSA	Association of Flight Attendants
AIDS:	Accidents and Incident Data Systems
AME:	Aviation Medical Examiner
ASHRAE:	American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.
ASRS:	Aviation Safety Research System
ARAC:	Aviation Rulemaking Advisory Committee
CAMI:	Civil Aerospace Medical Institute
C/B:	Chemical and biological
CFD:	Computational Fluid Dynamics
cfm	cubic feet per minute
CFR:	Code of Federal Regulations
CO:	Carbon Monoxide
CO ₂ :	Carbon Dioxide
DOD	Department of Defense
DOT:	Department of Transportation
ECS:	Environmental Control System
FAA:	Federal Aviation Administration
FAR:	Federal Aviation Regulation
HEPA:	High Efficiency Particulate Air
lbm	pounds mass
Medaire:	A worldwide aviation medical support system
NAS:	National Academy of Sciences
NASA:	National Aeronautics and Space Administration
NASDAC:	National Aviation Safety Data Analysis Center
NIOSH:	National Institute for Occupational Safety and Health
NO ₂ :	Nitrogen Dioxide
NRC:	National Research Council
NTSB:	National Transportation Safety Board
O ₃ :	Ozone
OSHA:	Occupational Safety and Health Awareness
PM:	Particulate material
RE and D	Research, Engineering and Development
REL	Recommended Exposure Limit
RSP:	Respirable Suspended Particulate
SDRS:	Service Difficulty Reporting System
TSA	Transportation Security Administration
VOC:	Volatile Organic Compound